

PATENT CLAIMS

1. A fiberoptic sensor for measuring at least one electric current or magnetic field, having
5 a light source (1),
N sensor heads (H_1, H_2, H_3) that can be arranged in the shape of a coil around current conductors (C_1, C_2, C_3) or along the magnetic field, N being a whole number with $N \geq 2$,
10 at least one phase modulation unit (PME; PME_1, PME_2, PME_3), having at least one phase modulator (PM; PM_1, PM_2, PM_3),
at least one detector ($2; 2_1, 2_2, 2_3$), and
a control and evaluation unit (5) that is connected via
15 at least one detector signal line ($D; D_1, D_2, D_3$) to the at least one detector ($2; 2_1, 2_2, 2_3$), and via at least one modulator signal line ($M; M_1, M_2, M_3$) to the at least one phase modulator (PM; PM_1, PM_2, PM_3),
first means (6) being provided for guiding light from
20 the light source (1) into an end ($3; 3_1, 3_2, 3_3$), on the detector side, of the phase modulation unit (PME; PME_1, PME_2, PME_3),
second means (7) being available for guiding light from the end ($3; 3_1, 3_2, 3_3$), on the detector side, of the phase
25 modulation unit (PME; PME_1, PME_2, PME_3) to the detector ($2; 2_1, 2_2, 2_3$),
the at least one phase modulation unit (PME; PME_1, PME_2, PME_3) having a further end ($4; 4_1, 4_2, 4_3$), on the sensor head side, that is optically connected to at
30 least one of the sensor heads (H_1, H_2, H_3), and
wherein by means of the at least one phase modulation unit (PME; PME_1, PME_2, PME_3) linearly polarized lightwaves can be phase-modulated differentially in a non-reciprocal fashion, characterized in that N modulation
35 amplitudes $\phi_{0,n}$ and N modulation frequencies ν_n are provided for the non-reciprocal differential phase modulations, the modulation frequencies ν_n and two prescribable positive whole numbers p, q with $p \neq q$

being selected in such a way that it holds for all positive whole numbers z and for all whole numbers n, m with $n \neq m$ and $1 \leq n, m \leq N$ that:

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$$p \cdot v_n \neq z \cdot v_m \text{ and}$$
$$q \cdot v_n \neq z \cdot v_m,$$

and the modulation amplitudes $\phi_{0,n}$ and the modulation frequencies v_n being selected as a function of modulation-relevant optical path lengths ℓ_n .

2. The sensor as claimed in claim 1, characterized in that exactly one control and evaluation unit (5) is provided, in which signals that originate from the various sensor heads (H_1, H_2, H_3) and are fed to the control and evaluation unit (5) via the at least one detector signal line ($D; D_1, D_2, D_3$) can be distinguished from one another by means of frequency filtering, it being possible to convert these signals into N output signals S_n , in particular it being possible to determine the output signals S_n for each n with $1 \leq n \leq N$ from signals at the frequencies $p \cdot v_n$ and $q \cdot v_n$ in the control and evaluation unit (5).

3. The sensor as claimed in one of claims 1 or 2, characterized in that exactly one phase modulation unit (PME) is provided, and in that N reflection interferometers are provided, each of the N reflection interferometers including exactly one of the N sensor heads (H_1, H_2, H_3), and the N sensor heads (H_1, H_2, H_3) in each case having a mirrored end ($13_1, 13_2, 13_3$).

4. The sensor as claimed in claim 3, characterized in that the light source (1) is connected to the control and evaluation unit (5) via a light control signal line (L), and in that a time division multiplexing method is provided for the measurement.

5. The sensor as claimed in one of claims 3 or 4, characterized in that the phase modulation unit (PME) either

(a) is a modulator circuit (PME) having N phase modulators (PM_1, PM_2, PM_3), in particular piezoelectric phase modulators ($PM; PM_1, PM_2, PM_3$), each of the N phase modulators (PM_1, PM_2, PM_3) being assigned to exactly one of the N modulation frequencies ν_n , and in that each of the N phase modulators (PM_1, PM_2, PM_3) can be operated at the modulation frequency ν_n assigned to it, and in that the differential phase of oppositely directed lightwaves polarized parallel to one another can be modulated, or

(b) includes a single phase modulator (PM), in particular an integrated optical phase modulator (PM), which permits a simultaneous phase modulation with the N various modulation frequencies ν_n , and it being possible to modulate the differential phase of lightwaves that propagate in the same direction and are mutually orthogonally polarized.

6. The sensor as claimed in one of claims 1 or 2, characterized in that N phase modulation units (PME_1, PME_2, PME_3) having one phase modulator (PM_1, PM_2, PM_3) each are provided, the nth phase modulation unit (PME_n) being optically connected to the nth sensor head (H_n), and it being possible to operate the nth phase modulator (PM_n) with the modulation frequency ν_n , and each of the phase modulators (PM_1, PM_2, PM_3) being connected to the control and evaluation unit (5) via one modulator signal line (M_1, M_2, M_3) each.

7. The sensor as claimed in claim 6, characterized in that N reflection interferometers are provided, each of the N reflection interferometers comprising exactly one of the N sensor heads (H_1, H_2, H_3), and the N sensor heads (H_1, H_2, H_3) in each case having a mirrored end ($13_1, 13_2, 13_3$), and

in that either

- (a) the phase modulation units (PME_1, PME_2, PME_3) are modulator circuits (PME_1, PME_2, PME_3), and in that it is possible to modulate the differential phase of oppositely directed lightwaves polarized parallel to one another by means of the phase modulators (PM_1, PM_2, PM_3), and in particular in that the phase modulators (PM_1, PM_2, PM_3) are piezoelectric phase modulators (PM_1, PM_2, PM_3), or
- (b) each of the phase modulators (PM_1, PM_2, PM_3) can modulate the differential phase of mutually orthogonally polarized lightwaves propagating in the same direction and, in particular, in that the phase modulators (PM_1, PM_2, PM_3) are integrated optical phase modulators (PM_1, PM_2, PM_3).

8. The sensor as claimed in claim 6, characterized in that N Sagnac interferometers are provided, each of the N Sagnac interferometers including exactly one of the N sensor heads (H_1, H_2, H_3), and in that each of the phase modulation units (PME_1, PME_2, PME_3) is essentially one phase modulator (PM_1, PM_2, PM_3) each, it being possible to modulate the differential phase of oppositely directed lightwaves, polarized parallel to one another, by means of the phase modulators (PM_1, PM_2, PM_3), and in particular, in that the phase modulators (PM_1, PM_2, PM_3) are piezoelectric phase modulators (PM_1, PM_2, PM_3) or integrated optical modulators (PM_1, PM_2, PM_3).

9. The sensor as claimed in one of the preceding claims, characterized in that selection $p = 1$ and $q = 2$ is made, and in that the N modulation amplitudes $\phi_{0,n}$ and the N modulation frequencies ν_n are selected in such a way that amplitudes $\alpha_{0,n}$ of the modulation of the differential phase of the linearly polarized lightwaves

lie between 1.7 and 2.0, in particular between 1.8 and 1.88, or are essentially 1.84 for all n with $1 \leq n \leq N$.

10. The sensor as claimed in one of the preceding
5 claims, characterized in that either

(a) exactly one detector (2) is provided, or

(b) N detectors ($2_1, 2_2, 2_3$) are provided, each of the
detectors ($2_1, 2_2, 2_3$) being connected to the control and
evaluation unit (5) via one detector signal line
10 ($D; D_1, D_2, D_3$) each.

11. The sensor as claimed in one of the preceding
claims, characterized in that $N = 3$ or $N = 6$, and the
electric currents of three phases of an electric high
15 voltage system can be measured by means of one sensor
head ($H_1; H_2; H_3$) each in the case of $N = 3$, or being able
to be measured by means of two sensor heads (H_n) each
in the case of $N = 6$.

20 12. A method for measuring at least one electric
current or at least one magnetic field, a light source
(1) emitting lightwaves that are converted into
linearly polarized lightwaves, and
the linearly polarized lightwaves being guided into
25 N sensor heads (H_1, H_2, H_3) in which the lightwaves
undergo a phase shift, which phase shift depends on the
current or magnetic field to be measured, N being a
whole number with $N \geq 2$, and

the lightwaves being detected in at least one detector
30 ($2; 2_1, 2_2, 2_3$), and

the lightwaves undergoing a non-reciprocal differential
phase modulation in at least one phase modulation unit
(PME; PME_1, PME_2, PME_3) having at least one phase
modulator ($PM; PM_1, PM_2, PM_3$), the at least one phase
35 modulation unit ($PME; PME_1, PME_2, PME_3$) being traversed by
the lightwaves both during their propagation from the
light source (1) to the sensor heads (H_1, H_2, H_3) and

during their propagation from the sensor heads
(H_1, H_2, H_3) to the at least one detector ($2; 2_1, 2_2, 2_3$), and
a control and evaluation unit (5) being used both to
control the at least one phase modulator (PM;
5 PM₁, PM₂, PM₃) and to evaluate signals originating from
the at least one detector ($2; 2_1, 2_2, 2_3$),
characterized in that

the lightwaves are differentially phase-modulated in a
non-reciprocal fashion with N modulation amplitudes $\phi_{0,n}$
10 and N modulation frequencies ν_n , the modulation
frequencies ν_n and two prescribable positive whole
numbers p, q with $p \neq q$ being selected in such a way
that it holds for all positive whole numbers z and for
all whole numbers n, m with $n \neq m$ and $1 \leq n, m \leq N$ that:

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$$p \cdot \nu_n \neq z \cdot \nu_m \text{ and} \\ q \cdot \nu_n \neq z \cdot \nu_m,$$

and the modulation amplitudes $\phi_{0,n}$ and the modulation
20 frequencies ν_n being selected as a function of
modulation-relevant optical path lengths ℓ_n .